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Device and Method for Scanning and Image Acquisition with Multi-slot Collimator System for X-ray Imaging

The usual systems for x-ray imaging consist of an x-ray source and an area detector placed behind the object to register the image. The main drawback with this set-up is its sensitivity to background noise in form of Compton scattered radiation. Existing methods to remove this background are inefficient and also remove a fraction of the primary x-rays that contains the image information. This results in a dose increase that can be as high as a factor 3.

One way around this problem is a scanned-slot set up. A pre collimator slot before the object shapes the x-ray beam to match the active detector area. The slot is moved mechanically to image the whole object. It is also possible to have the object moving with respect to the slot, this is however usually more inconvenient because the object is usually heavier than the mechanics for the slot. Since only a narrow fan-beam is crossing the object at any single time the amount of Compton scattered x-rays is minimized. Another advantage with the scanned-slot approach is that the required detector area is much smaller, this cuts cost and also enables the use of more expensive and efficient detector materials if desired.

A drawback with the scanned-slot geometry is that only a small fraction of the x-rays from the source is actually used to form the image. As a results the time for image acquisition is extended and the x-ray tube need to be turned on for a longer period of time. A way of mitigating this problem and achieve a practical system is to use a multi slot collimator with different detector arrays under each slot. This however makes the image acquisition non-trivial since the information from the different detectors has to be sewn together into one image without any visible artifacts such as boarder lines between areas where different detectors were used.

In this patent we present a method to solve the problem of acquiring a high quality image without artifacts using a multi-slot detector system. A particular advantage is the robustness of the system with respect to non-functioning, so called dead, channels and the low sensitivity to deterioration of spatial resolution due to motion in the object.

Preferred Embodiment of the Inventions

A preferred embodiment of the invention is a multi slot system for mammography according to Fig. 1. Indicated as 101 is the x-ray source, in 102 is a first rough collimator while collimators 119 define the over all field of view 118 The multi slot collimator 103 in this case has 5 slots 115 cut through the metal. A top view of the collimators 103 and 105 with the cut through slots indicated as lines is displayed to the left. After the multi slot collimator is the x-ray object 104 and one can image everything inside the said field of view. The x-ray object for mammography is the female breast and this is compressed according to the standard technique using compression pedals 116. After the object a second collimator 105 is placed and the slots in this collimator is matched to the collimator 103 above so that the x-rays coming straight from the source, without

deflections, and pass collimator 103 will also pass collimator 105. A good material for collimators is Tungsten since it has a high stopping power and very small scattering probability for the x-rays. The collimators could also be made of other heavy metals such as Copper or stainless steel. After the collimator 105 a sensor array is placed 106 under each slot in such a way that all x-rays coming straight from the source without deflections that pass collimator 103 and pass collimator 105 will also hit the sensor arrays beneath the slots and be registered by dedicated electronics. The collimator 103 and collimator 105 will be placed on one mechanical support 108 together with the sensor arrays 106. This support will be connected to an accurate linear stage that can move the slots relative to the object. The stage should be computer controlled and be equipped with an accurate position reading. While the slots are moving data from the sensor arrays are read out together with the present coordinate according to the position reading. From this information the image is reconstructed.

The sensor arrays and electronics could for example consist of a scintillator optically connected to a CCD. The sensor arrays could also be made of silicon diodes and a dedicated electronic circuit could count each x-ray. It would also be possible to use a gaseous detector, such as a Parallel Plate Chamber where the gas volume is oriented edge-on to the incident x-rays and the pulses induced by the x-rays in the gas can be counted by a dedicated electronic circuit. To prevent scattered x-rays from one detector array reaching neighboring detector arrays an absorbing plate such as a thin Copper plate can be inserted between each of the slits.

Said electronic circuits are state of the art and can be ordered for example from Sicon AB in Linköping, Sweden. Silicon diodes can be ordered e.g. from Detection Technology, Finland and gas detectors can be manufactured at CERN, Geneva. Said electronic circuit is connected to a computer where the data is transferred for manipulation, corrections and display.

Before the scan starts all slots should be placed substantially outside the field of view. After the scan starts it should have reached a constant speed before the first pair of slots (103 and 105) enters the field of view. During the scan, the data containing information about the number of x-rays hitting the detector should be read out as frequently as possible. The data for one read out will consist of a vector of numbers representing the x-ray flux in each of the pixels of the sensor array and this vector will be stored. When the scan is finished the image resulting from one array of vectors will consist of a matrix of all the vectors from the individual readouts.

To be more specific about the read out rate, we give an example where the width of the sensors is 50-µm. In this case the data should preferably be read out at least every 25-µm corresponding to half the width of the array. This is to sampling according to the well-known Nyquist frequency and would prevent any large loss of information due to sampling in to large steps. It would also prevent artifacts due to aliasing. It would not hurt to sample more frequently than this. One would not like to sample in steps larger than 50-µm, the width of the array, since in this case the image for a certain array will be incomplete. Generally one would like to readout data in time intervals more frequent than it takes for the slots to move a distance equal to half the size of the sensor arrays.

The scan should continue until all slots have substantially passed the field of view. There will now be information enough to create one image for the data coming from the sensor arrays for each of the slots. If we have N slots we will now have N images and the

overall image is formed as the superposition of all said images. This is a straightforward operation and only involves simple superposition of images and there is no need to seem several sub-images together. Dead individual sensors could simply be corrected for since information at this image point also exists in sensors at adjacent slots. The sensor arrays in the different slots could be slightly offset with respect to each other in order to avoid aliasing and sample according to the Nyquist criteria also in the dimension perpendicular to the scan direction.

The system will only be sensitive to motion in the object in a timeframe defined by the time it takes the slits to move corresponding to the distance between the first and the last slit. This time is usually considerably less than the total scan time.

Claims

1. A device for obtaining improved image quality in x-ray imaging procedures, comprising

an essentially planar member of a material non-transparent to x-rays, having at least two elongated slots formed therein;

an array of sensors provided below said slots and arranged to detect x-rays and providing a signal representative of the intensity of said x-rays impinging thereon;

means for moving said planar member with respect to an object to be examined by x-ray imaging; and means to acquire and read out data from said sensor arrays at intervals corresponding to a fraction of the width of said sensor arrays

2. The device according to claim 1 with the sensor arrays made of silicon.

3. The device according to claim 1 where the sensor arrays are made of silicon wafers oriented substantially edge-on to the incident x-rays.

4. The device according to claim 1 where the sensor arrays comprises gaseous detectors.

5. The device according to claim 1 where the sensor arrays consist of gaseous detectors with the gas volume oriented edge-on to the incident x-rays.

6. The device according to claim 1 were the slots are split in the direction orthogonal to the scan into between 2 and 50 smaller slots

7. A method for scanning using the device as claimed in 1 such that

when the scan starts all slots and corresponding sensor arrays are substantially outside the field of view;

all slots and corresponding sensor arrays passes the object and thus the said field of view and during the scan x-ray flux is measured together with position coordinates for all sensors in the different arrays;

the scan stops only after all slots and corresponding sensor arrays are substantially outside the field of view.

8. The method according to claim 7, wherein the scanning is incremented at least a distance corresponding to a fraction of the width of the sensor array, preferably at least 1/8 of said width, most preferred over at least ½ of said width.

9. The method according to claim 7, wherein the scan is continuous and wherein read-out of data is performed at intervals corresponding to a fraction of the width of the sensor array, preferably at least 1/8 of said width, most preferably over at least ½ of said width.

10. The method as claimed in any of claims 7-9, wherein the read-out data for each increment and for each sensor array are stored as data arrays, and wherein the stored data for each sensor array are separately combined to form an image, and wherein the images obtained by each sensor array are superposed to form a final image.

11. An x-ray imaging system, comprising

a source of x-rays;

x-ray collimators provided in the x-ray path;

a means for locating an object to be examined;

a device as claimed in claim 1, operatively coupled with said means for locating the object to be examined;

a control system for controlling the dose of x-rays, scanning, acquisition and storage of data and data processing required to form a final image.

12. An x-ray imaging system consisting of

at least two pairs of said slots

an array of sensors under each slot

a collimator defining a field of view for the system

means for moving the slots and sensor arrays with respect to the object

absorber plates, placed between the sensor arrays and slots to absorb scattered radiation and prevent this radiation to reach neigboring sensor arrays.

13. The device according to claim 1 and the method according to claim 7 where the application is digital mammography.

14. The device according to claim 1 and the method according to claim 7 where the number of slits are more than 2 and less than 100.

Fig 1 - Front view